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RESEARCH PAPER
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Weibull analysis of tensile properties of banana natural fibre

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ABSTRACT

The banana fibres are natural fibres obtained from agricultural wastes having high biomass. These fibres find a unique place in the composite industry as reinforcements as a substitute for glass to cut down production cost as well as making it biodegradable. The banana fibre being rich in cellulose similar to cotton and low in lignin proves to be an ideal raw material for paper and textiles. The manually extracted banana fibres were treated with different concentrations of NaOH and the tensile properties were measured. The alkali treatments applied to the banana fibre caused considerable loss of strength at higher concentrations. The fibre swelling was noticed with an increase in diameter of the treated fibre. The Weibull distribution is found to be a useful tool to explain the strength variation of natural fibres. The banana natural fibre has high degree of linearity in the breaking strength both in the untreated fibre and treated fibre. The Weibull modulus of Banana natural fibre was in the range of 1-6 common to most natural fibres and proved to be a good representation of the data.

Key Words : Tensile strength, Weibull analysis

INTRODUCTION

Cellulosic fibres are the most abundantly occurring natural fibre and it occupies an important position among the raw materials for the textile industry. Natural fibres are also finding an unique place in the composite industry as reinforcements replacing synthetic fibres and glass because of their lower cost of production and higher strength.

There are a few minor fibres such as hemp, jute, bamboo and ramie that have gained much commercial value because of their ecofriendly nature and excellent serviceability. Still there remain several more promising lignocellulosic fibres that can be exploited for textile benefits.

Advances in research and technology have stated that annual crops or agricultural wastes can be used as favourable alternative sources as the raw material for the natural fibre (Cordeiro *et al.,* 2004). Banana plant provides one such biomass which can be utilized effectively.

Banana is one among the most favourite and important of all tropical fruits. It is grown in 135 countries throughout the world. India leads the world in banana production with an annual output of about 29.82 mt. (FAOSTAT, 2015). Usually, after harvesting the stem is discarded. A large quantity

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of bio waste is generated every year owing to banana cultivation. This bio waste can be utilized to extract fibre which has varied use.

Banana fibres obtained from the pseudostem of banana plant are leaf fibres that are complex in structure, consisting of helically wound cellulose microfibrils in amorphous matrix of lignin and hemicelluloses (Mukhopadhyay *et al.,* 2008). The length of the banana fibre varied from 89-110 cm. Its fineness was about 130 denier, moisture regain almost 8.63% and tensile strength 40.5 g/tex (Shroff *et al.,* 2015). The tenacity of fibres was higher (46.36 g/tex and 54.92 g/tex) than cotton fibre (Mishra and Goel, 1999). The diameter of the fibre ranged between 80-250 μm with elongation percentage of 1.0 – 3.5 (Reddy and Yang, 2005).

It has been reported that the quality of matrix composed mainly of lignin and hemicellulose exerts strong influence on tenacity (Mukherjee and Sathyanarayana, 1986). Hence different cultivars showed a variation in tenacity. The tenacity of plantain fibre (385 Mpa – 583 Mpa) was higher than that of banana fibre (380 Mpa -650 Mpa) (Akubueze *et al.*, 2015).

Weibull statistics has been used to analyse the properties of natural fibres like jute, hemp, flax, bamboo, sisal and cellulose (Hashim and Oleiwi, 2016). Weibull analysis was used to study the tensile properties of wool fibres with geometrical irregularities. A new Weibull model was introduced which not only took in account the fibre to fibre diameter variation but also the within fibre diameter variation (Zhang and Wang, 2002).

The tensile properties of coir fibre using Weibull distribution was studied which indicated a high linearity and good tensile strength of the fibres (Hashim and Oleiwi, 2016).

The tensile properties of ring and rotor yarns of cotton, polyester and cotton polyester was investigated using Weibull analysis. The tenacity of the yarns decreased with the increase in the gauge length and fitted well with the Weibull model. The strength variation was higher at lower gauge lengths in all the cases (Raghunathan *et al.,* 2002).

Hence, the present study, explores the tensile properties of treated and untreated fibres applying the Weibull statistics to assess the variability in strength.

METHODOLOGY

The banana fibres for the study was manually extracted and procured from YMCA unit of Martandam, Tamil Nadu.

The chemicals used for the study were Sodium hydroxide, Acetic acid and Sodium carbonate which were of analytical grade were purchased from Chemind, Thrissur, Kerala.

Method of treatment :

The banana fibres were treated with sodium hydroxide in concentrations of 0.5%, 1%, 2% and 3% (w/v) at room temperature for 30 mins with a material to liquor ratio of 1:30. The fibres were then washed in lukewarm water 3-4 times and then neutralized with 0.1% (w/v) of Acetic acid with 1:30 material to liquor ratio for 2-5 minutes. The fibres were then washed thoroughly with distilled water.

Test Method :

The tensile parameters were tested on Instron 3345 system. Single fibres tests of control and treated fibres were carried out with 10 readings each. The guage length used was 65 mm with a crosshead speed of 100mm/min.

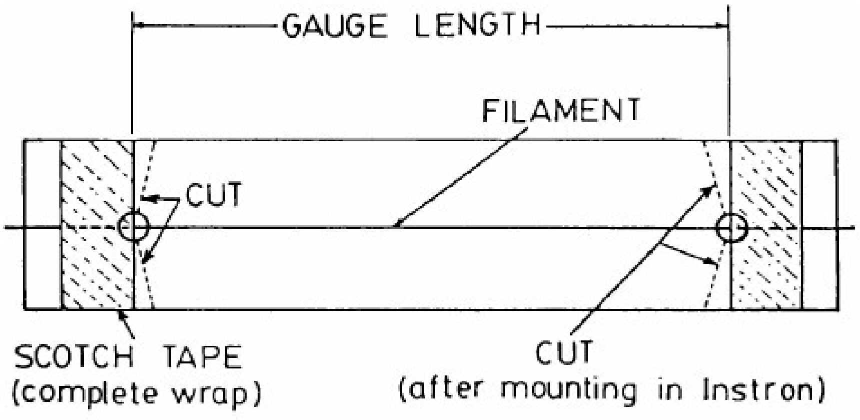

Fig. 1 : Typical specimen mounting (Wagner *et al.*, 1984)

RESULTS AND DISCUSSION

Tensile properties of the fibre :

The tenacity of the banana fibre shows a decrease. Alkali treatment caused strength loss which varied from 25% to 57%. The maximum load required to break the fibres decreased as the concentration of the alkali increased and the fibre sample proved to be weaker with higher concentrations of alkali.

Table 1 : Tensile properties of untreated and alkali treated banana fibres

Fibre	Tenacity (MPa)	Extension (%)
Untreated	151 (40.5)	0.8
Treated fibre 0.5%	113 (57.9)	0.7
1%	*98 (39.3)	0.7
2%	*64 (64.5)	0.6
3%	*65 (38.3)	1

**Figures in parenthesis indicate coefficient of variation, *t values significant

When compared with the untreated fibre, the value of the t statistic was found significant at 5% level in the tenacity values at all concentrations except at concentration of 0.5%

Weibull analysis is mostly described as the weakest link model as it describes the probability of the weakest element in a chain of elements failing and hence causing the failure of the specimen. The shape parameter or Weibull modulus characterises the scatter in strength of a material. The Weibull modulus is determined for the control and treated samples with various concentrations of alkali used.

Table 2 : Effect of Alkali treatment on weibull modulus of breaking strength of banana fibres

Sr. No.	Type of treatment	Weibull modulus (β)	R^2	Characteristic value (Kgf)	Experimental value (kgf)	CV% for breaking load
1.	Untreated	2.45	0.90	0.31	0.27	40.5
2.	0.5%	1.69	0.94	0.26	0.2291	57.9
3.	1%	2.27	0.94	0.22	0.1933	39.3
4.	2%	1.46	0.92	0.14	0.1277	64.5
5.	3%	2.48	0.95	0.28	0.2485	38.3

In Fig. 2 it can be seen that the characteristic value is higher than the experimental value. In the Fig. 3, a high linear regression is observed for the breaking strength of untreated banana fibres ($R^2 = 0.90$). The R^2 values indicate a high degree of linearity for both untreated as well as treated fibres.

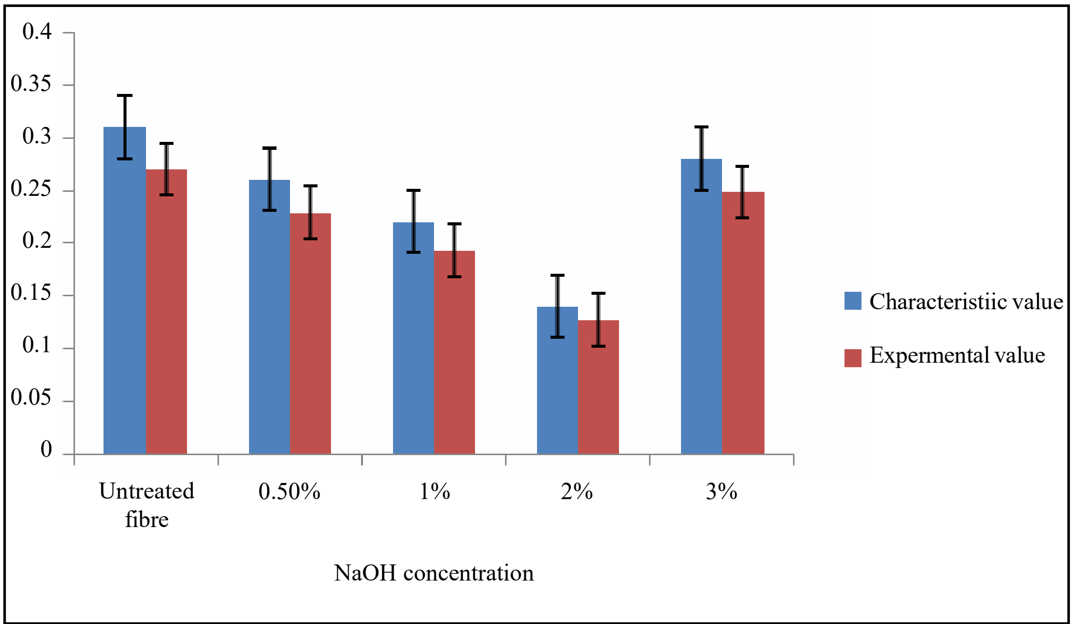

Fig. 2 : Characteristic and experimental values of breaking strength of banana fibres treated with NaOH by the Weibull model

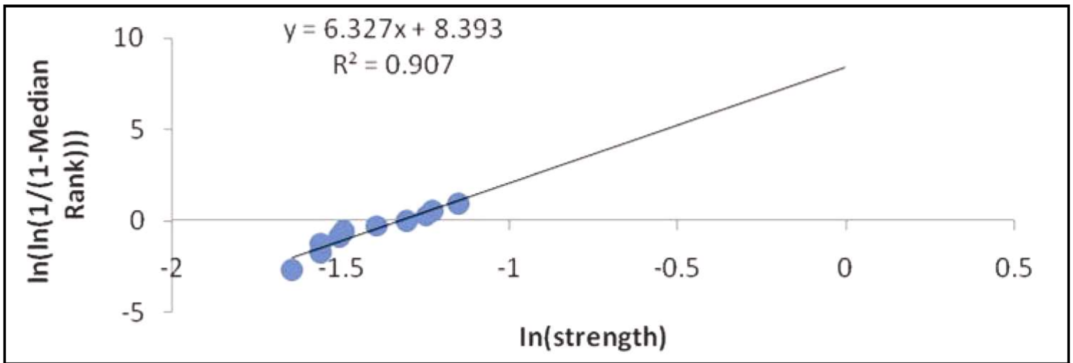

Fig. 3 : Weibull distribution of banana natural fibre strength of Untreated banana fibres

Weibull distribution by linear regression and Method of moments :

The Weibull modulus values obtained by two methods *viz*., Linear regression and Method of moments (Fig. 4) is in good agreement in most cases. For most natural fibres the weibull modulus is in the range of 1-6 which is seen for untreated and treated banana fibres (Hashim and Oleiwi, 2016). The lower value of the Weibull modulus indicates high scatter or variability in its tensile strength, which may be attributed to the diameter variations (0.11- 0.24mm) between the fibres.

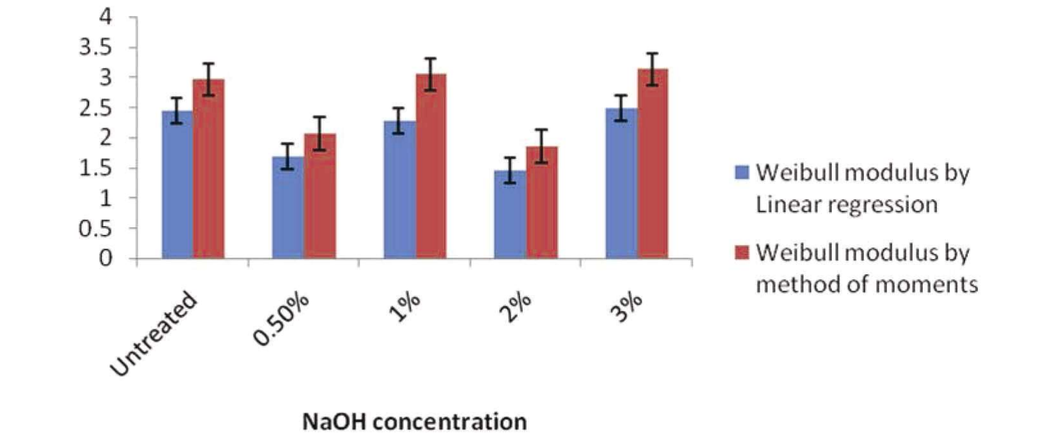

Fig. 4 : Weibull Modulus by Linear regression and Method of moments for the breaking strength of banana fibres treated with NaOH

Fitness of Weibull distribution of banana fibre breaking strength :

To verify whether the breaking load obeys the Weibull model, the Kolmogorov Smirnov goodness of fit test was used. The sample statistical distribution and theoretical distribution using the Weibull parameters were calculated for the maximum difference between them was denoted as D_n.

The D_n values were found to be less than the critical value computed from the table at 5%, n=10. Hence it can be concluded that the statistical model is considered as a good representation of the data distribution.

Table 3 : Fitness of Weibull model for NaOH treated Banana Fibres

Type of treatment	Weibull modulus (β)	Characteristic value	D_n	D_{nc}
Untreated	2.45	0.31	0.04	0.4
0.5%	1.69	0.26	0.03	0.4
1%	2.27	0.22	0.02	0.4
2%	1.46	0.14	0.0123	0.4
3%	2.48	0.28	0.0315	0.4

D_n- difference between the statistical distribution & theoretical distribution, D_{nc}- table value

Conclusion :

Like all other natural fibres, the untreated and treated banana fibres show high variability in their breaking strength. The banana natural fibre has high degree of linearity in the breaking strength both in the untreated fibre and treated fibre. Treatment with alkali reduces the tenacity of the fibre. The statistical values that form the distribution are close to the theoretical values measured for the breaking load of the fibres treated with alkali. The characteristic values are higher than the experimental values. The Weibull modulus calculated by the two methods *viz*. linear regression and Method of moments were in close agreement. The Weibull modulus was in the range of 1-6 which is the range for most natural fibres like banana that have more variation in properties.

Hence the statistical distribution or the weibull model is a good representation of the data as proved by the Kolomogorov Smirnov goodness of fit test.

REFERENCES

Akubueze, E.U., Ezeanyanaso, C.S., Orekoya, E.O., Ajani, S.A., Obasa, A.A., Akinboade, D.A., Oni, F., Muniru, O.S., Affo, G. and Igwe, C.C. (2015). Extraction and production of Agro Sack from banana (*Musa sapientum*) and plantain (*Musa paradisiaca*) fibres for packing agricultural produce. *Internat. J. Agric. and Crop Sci.*, **9** (1): 9-14.

Cordeiro, N., Belgacem, M.N., Torres, I.C. and Moura, J.C.V.P. (2004). Chemical composition and pulping of banana pseudostems. *Industrial Crops & Products,* **19**: 147 -154.

FAOSTAT – Production/Crops (2015). www.fao.org

Hashim, A.M. and Oleiwi, J.K. (2016). Tensile properties distribution of coir natural fibre using weibull statistics. *Engg. & Technol. J.,* **34**(6): 1080-1087.

Mishra, V. and Goel, A. (1999). Softening of Banana fibre. *Indian Textile J.,* **110**(11):34-35.

Mukherjee, P.S and Sathyanarayana, K.G. (1986). An empirical evaluation of structure – property relationships in natural fibres and their fracture behavior. *J. Materials Sci.,* **21**: 4162 – 4168.

Mukhopadhyay, D., Fangueiro, R., Arpac, Y. and Sentrik, U. (2008). Banana fibres – variability and fracture behaviour. *J. Engineered Fibres & Fabrics*, **3**(2) : 139-145.

Raghunathan, K., Subramaniam, V. and Srinivasamoorthy, V.R. (2002). Studies on the tensile characteristics of ring and rotor yarns using modified Weibull distribution. *Indian J. Fibre & Textile Res*., **27**:358-361.

Reddy, N. and Yang, Y. (2005). Biofibres from Agricultural byproducts for Industrial applications. *Trends Biotechnol.,* **23**(1):22-27.

Shroff, A., Karolia, A. and Shah, J. (2015). Biosoftening of banana fibre for nonwoven Application. *Internat. J. Scientific Res.,* **4**(4):1524 -527.

Tian, L., Chen, S.Y. and Bi, X.Y. (2013). The effect of alkali treatment to the properties of banana fibres. *Appl. Mechanics & Materials,* **268 – 270** : 258-261.

Wagner, H.D., Phoenix, S.L. and Schwartz, P. (1984). A study of statistical variability in the strength of single Aramid filaments. *J. Composite Materials,* **18**:312. DO1:10-1177/002199838401800402.

Zhang, Y. and Wang, X. (2002). Weibull analysis of the tensile behaviour of fibres with geometrical irregularities. *J. Material Sci*., **37**: 1401-1406.

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